Design Feature

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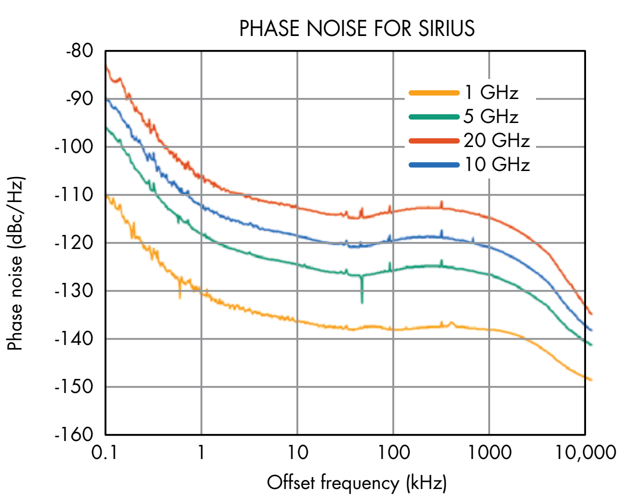
Check the Specs When Selecting a Signal Generator

During the process of choosing an instrument, it's wise to become keenly aware of key specifications in order to properly match it with a particular application's requirements.

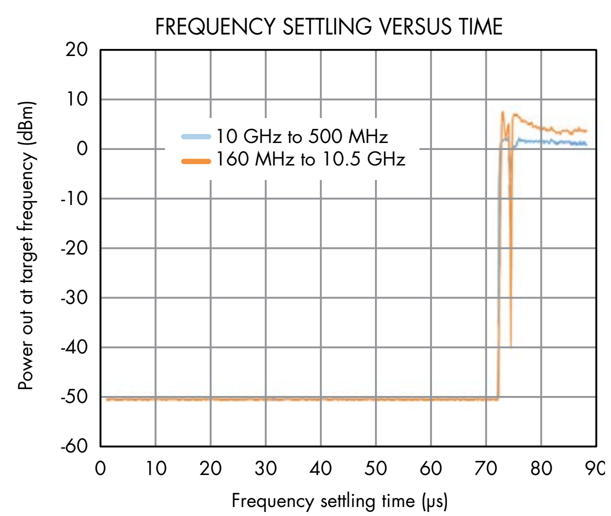
Testing of RF/microwave semiconductors, components, and systems incorporated in everything from commercial wireless systems to military radar applications often involves the ubiquitous signal generator. These instruments may be employed for continuous-wave (CW) or pulsed signal generation, local-oscillator (LO) substitution when evaluating receivers and transmitters, and stimulus and response measurements.

When selecting a signal generator for an RF/microwave test system,[1] it is important to understand the key specifications like output power, phase noise, level accuracy, spurious levels, and harmonics. However, one shouldn't take a casual approach to such details as frequency switching speed and calibration time, which may be critical to a particular application.

The limits of a signal generator will be the limits of a measurement system's capabilities, especially when characterizing high-performance devices under test (DUTs). For example, when testing an amplifier with a signal generator exhibiting high levels of harmonic distortion or spurious signal content, it becomes difficult to determine whether a test system's analyzer is measuring the amplifier's or signal generator's performance. By better understanding signal-generator specifications, one is able to more clearly discern the tradeoffs between price and performance, and the right source can be found for a particular application.



1. These are the typical phase characteristics for a commercial signal generator, which in this case is the modular PXIe-5654 from National Instruments.



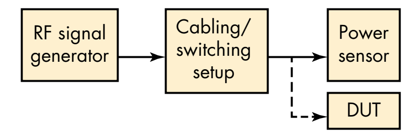
2. The frequency-settling-time characteristics of the NI PXIe-5654 are plotted for frequency transitions of 10.0 to 0.5 GHz (blue trace) and 160 MHz to 10.5 GHz (orange trace).

PHASE NOISE, OTHER VITAL SPECS

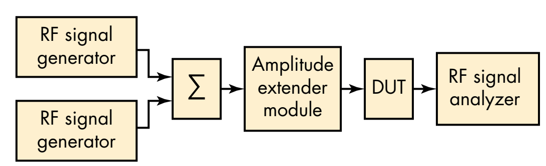
Test-and-measurement requirements vary according to the end system, but for many applications, including communications and radar systems, signal-generator phase noise *(Fig. 1)* is critical in determining the dynamic range and signal sensitivity of a test system. High phase noise reduces a radar system's efficiency in resolving closely spaced targets or tracking slow- and fast-moving targets simultaneously. Similarly, in wireless comm systems, high phase noise reduces a receiver's selectivity to switch between narrow radio channels, leading to high bit error rates (BERs).

CW signal generation in verification tests such as intermodulation-distortion (IMD) measurements, noise figure measurements, phase-noise tests, and third-order-intercept (TOI) measurements requires a signal generator with high spectral purity. High spectral purity refers not only to low phase noise, but also low harmonic levels and low spurious content.

The harmonic performance of a signal generator must be analyzed separately from other spectral-purity parameters (e.g., spurious noise or phase noise), depending on the application under test or the frequencies required for a test. In general, a signal generator will not exhibit low harmonics across its entire frequency range. However, some signal generators are designed with internal filters, such as highpass filters, to reduce harmonic signal levels across different frequency bands. This is generally true at low frequencies for a broadband signal generator.



3. A power meter connected to the output of a signal generator can help save time and minimize amplitude settling errors when switching frequencies.



4. ATE testing is aided by flexibility, as in this case of a single model NI 5696 amplitude extender module used with a pair of NI PXIe-5654 signal generators for two-tone testing.

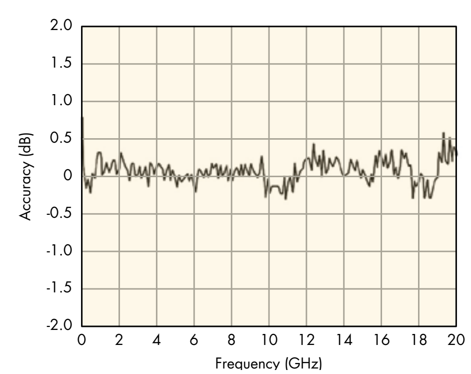
Switching speed is an important signal-generator parameter for many applications, like when testing frequency-hopping radios. Fast switching synthesizers also can be valuable for production testing, since higher-frequency switching speeds mean faster test times and higher product throughput. When a signal generator or frequency synthesizer spends less time transitioning from one frequency to another during a sweep or a sequence of test frequencies, more time is available to execute measurements.

Signal generators have historically incorporated yttrium-iron-garnet (YIG) oscillators as signal sources when low phase noise was required, and voltage-controlled oscillators as signal sources when there was a need for fast frequency tuning. Because of the two traditional architectures, the notion has arisen that fast switching speed and low phase noise are mutually exclusive signal-generator parameters. However, some applications, such as testing RF integrated circuits (RFICs), may demand both low phase noise and fast switching speed.

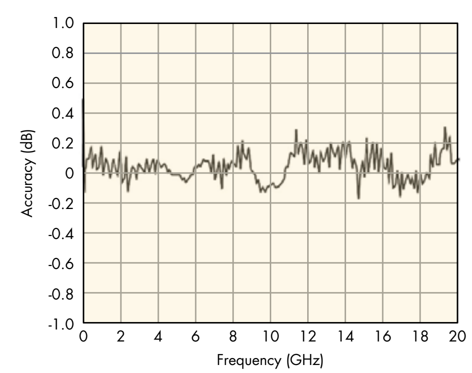
One example of an instrument that handles both parameters is the NI PXIe-5654 modular RF signal generator from National Instruments, which operates from 250 kHz to 20 GHz. It employs a low-phase-noise oven-controlled crystal oscillator (OCXO) that is optimally translated to the range of output frequencies while maintaining the OCXO's low-phase-noise profile.

The typical phase-noise characteristics of the signal generator are shown in Fig. 1.[2] For example, at 20 GHz, the single-sideband (SSB) phase noise is –113 dBc/Hz offset 10 kHz from the carrier. It improves to –119 dBc/Hz offset 10 kHz from a 10-GHz carrier, notably better than the phase-noise performance of many microwave YIG-based synthesizers. Further from the carrier, the phase noise of the PXIe-5654 remains flat for several megahertz and then drops down to the noise floor.

Since the signal generator is based on a VCO architecture, it also provided fast frequency switching speeds.[3] At lower frequencies, phase noise improves by 6 dB/octave due to frequency division.



5. This is the typical measured power accuracy of an NI PXIe-5654 signal generator at –100 dBm.



6. This is the typical measured power accuracy of an NI PXIe-5654 signal generator at –70 dBm.

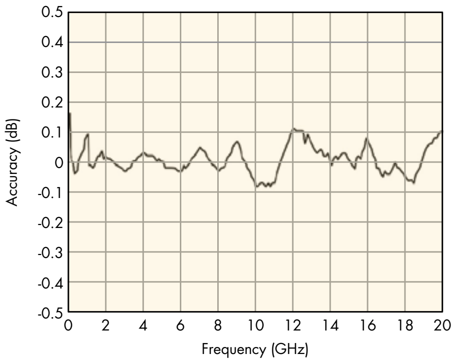
SETTLING TIME

Manufacturers are under pressure to increase production-line throughput while decreasing the cost of test. At the same time, test engineers pursue more measurement data without significantly lengthening the time required for measurements. When using a signal generator, it is critical that a test engineer be familiar with all factors that impact frequency switching time and amplitude settling time.

Figure 2 shows the frequency-settling-time characteristics of the NI PXIe-5654.[4] Two separate frequency transitions are given: The vertical axis shows output power at the target frequency, while the horizontal axis reveals the time following the trigger used to initiate a change in frequency. The blue curve indicates a frequency transition from 10.0 to 0.5 GHz, and the orange curve shows a transition from 160 MHz to 10.5 GHz.

In both cases, the frequency settles to within 5 ppm of the target frequency well within 100 µs. The instrument's VCO-based architecture makes it possible to achieve fast frequency-switching speeds throughout the frequency tuning range without depending on the size of the jump in frequency.

Amplitude settling errors will play a part in a signal generator's settling time, with fewer errors usually requiring longer switching times. If some amplitude errors can be tolerated in a measurement, faster settling times are possible. For example, with an NI PXIe-5654 signal generator, if greater than 2-dB amplitude settling error can be tolerated, a 100-point sweep can be completed in about 30 ms.



7. This is the typical measured power accuracy of an NI PXIe-5654 signal generator at –40 dBm.

By performing such a measurement in list mode, amplitude errors can be measured and corrected for all points with the aid of a power meter *(Fig. 3)*. This technique can ultimately shave off hundreds of milliseconds to seconds from every frequency sweep.

Understanding how software, such as list-mode functions, can be applied to a particular signal generator helps decrease test time while still minimizing amplitude settling errors. Switch points (frequency and power-based) and mechanical attenuators can add significant time to frequency sweeps with hundreds of points.

However, changing the state of an instrument's mechanical attenuator can decrease settling time by 20 ms. For example, the datasheet for the NI PXIe-5654 provides guidance on how factors such as mechanical attenuators can impact sweep times.

FLEXIBLE ARCHITECTURE

High-volume production testing often requires multiple racks of test signal generators. Modular instruments such as the PXI-based NI PXIe-5654 occupy a fraction of the volume of traditional 19-in.-wide rack-mount instruments while allowing for additional complementary, compact modules like the PXIe-5696 amplitude extender module. This module's amplitude level control (ALC) performs corrections in the amplitude control circuitry of the PXIe-5654, resulting in a leveling of power from –110 to +30 dBm across a frequency range of 250 kHz to 20 GHz.

To illustrate the flexibility possible with a modular architecture, two PXIe-5654 signal generators were used with a PXIe-5696 amplitude extender module for two-tone power-amplifier (PA) and front-end-module (FEM) testing *(Fig. 4)*. Normally, a single module would be insufficient to make amplitude corrections for two separate signal generators. But in this case, the flexibility allows for simplified two-tone testing, with signals from a PA or FEM fed to a signal analyzer for evaluation.

A signal generator's output power is another important specification because of the loss of signal power through cables and switches leading to a DUT in a test setup. When specifying a test signal source, sufficient margin should be allocated for output power to compensate for such losses in the test setup. It is much easier to drop signal levels with an external attenuator (which is passive) than to boost signal levels with an external amplifier (which requires bias energy).

Some tests (e.g., PA characterization) require high signal output levels from a signal generator while maintaining high level accuracy and good spectral purity. Power accuracy is critical because a DUT's response is likely to vary with the signal-generator power level. For such requirements, multiple RF attenuators may be used to extend the dynamic range of a signal generator's output power, along with an ALC circuit to increase the accuracy of the output signal.

To demonstrate how power accuracy can change at different signal-generator output-power levels, the typical power accuracy of the PXIe-5654 signal generator with a PXIe-5696 module is plotted in *Figs. 5, 6,* and *7* for output levels of –100, –70, and –40 dBm, respectively. MW

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